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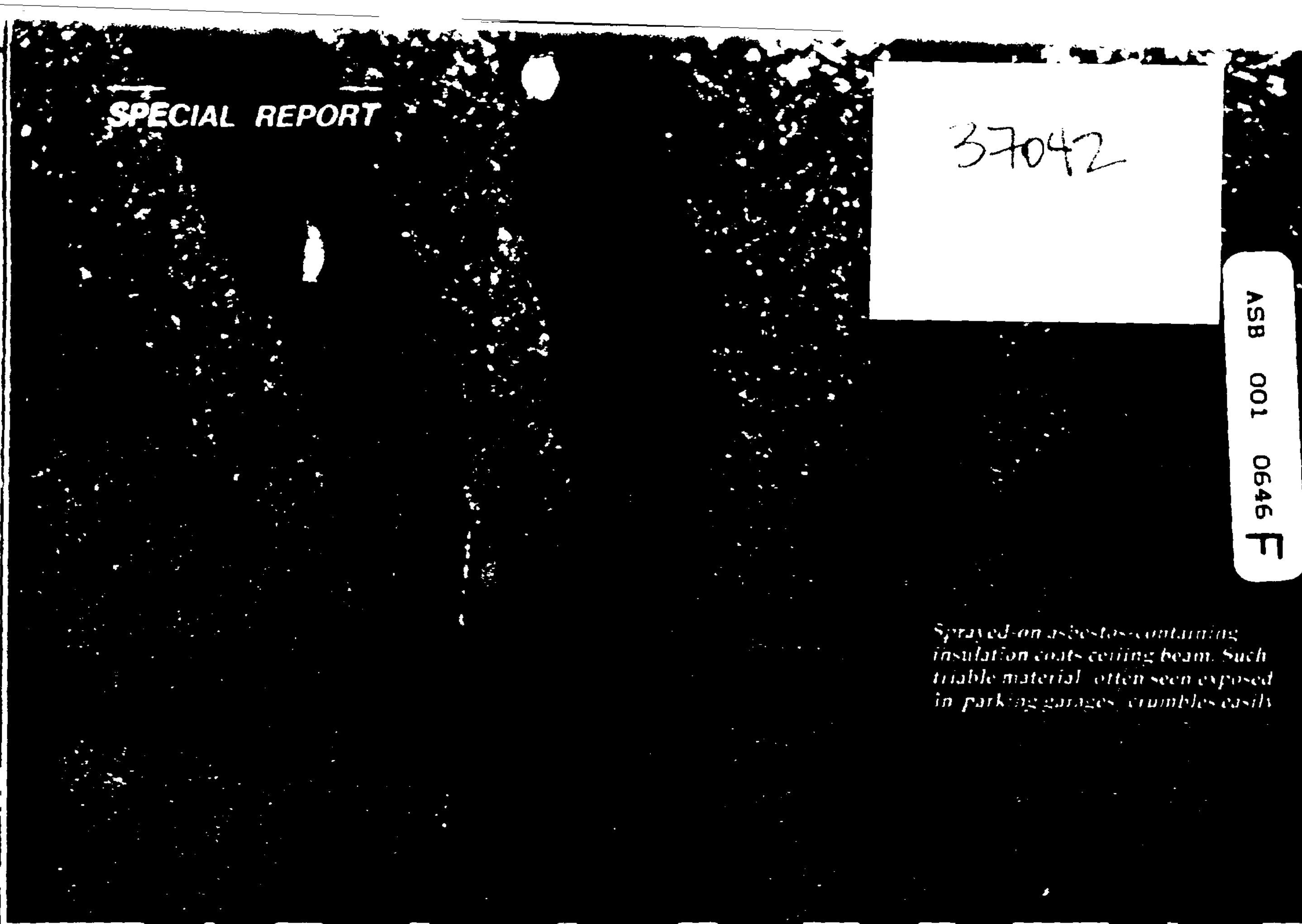


Sprayed-on asbestos-containing insulation coats ceiling beam. Such friable material, often seen exposed in parking garages, crumbles easily

ASBESTOS

The fiber that's panicking America

Pamela S. Zurer, C&EN Washington

March 1984 – The Environmental Protection Agency assesses a $24,000 fine against three schools in Goffstown, N.H., for failing to comply with EPA's rule concerning asbestos in schools.

December 1984 – The District of Columbia files a $400 million lawsuit against asbestos manufacturers and distributors to recoup the cost of removing asbestos from city buildings.

January 1985 – Fairfax County, Virginia, government announces it will spend $5 million to $6 million to remove asbestos from three public buildings, even though it says air levels are not hazardous.

Demand for asbestos in the U.S. last year was only about 30% of what it was at its peak in 1973. Fear of the material's toxicity and the health-related lawsuits it has engendered are largely to blame. But demand has been mushrooming for the services of the asbestos abatement industry, as property owners rush to remove asbestos that was used as fireproofing and insulation in many buildings built before the mid-1970s. Demand for legal expertise is increasing, too, with property damage suits multiplying rapidly.

Two decades ago, concerns about asbestos hazards centered on workers who had been exposed to huge amounts of fibers in their jobs. In the 1960s, landmark epidemiological studies by Irving J. Selikoff of Mount Sinai School of Medicine and E. Cuyler Hammond of the American Cancer Society showed that insulation workers who had dealt with asbestos for 20 years or more were dying of cancer and the complications of asbestosis at alarming rates. Later, a few people whose only contact with the material was that they lived in the same house as asbestos workers were found to be dying of mesothelioma—a rare cancer of the lining of the lung or abdomen.

In 1971, asbestos became the first material to be regulated by the then-new Occupational Safety & Health Administration. In 1982, lawsuits filed by workers suffering from asbestos-related diseases led Manville Corp.—once the largest U.S. asbestos producer but since

1983 out of that business—to look for an escape from the rising costs in bankruptcy court.

Today, although there is still concern that people who work with asbestos are not protected adequately, fear is mounting over the long-term effects of exposure to asbestos in the general environment. Asbestos fibers can be found in the air almost anywhere if you look hard enough. Sources of asbestos in outdoor air range from natural rock to mining and manufacturing operations to particles released from the brake linings of cars and trucks. Indoors, aging or damaged building materials can release asbestos into the air.

Anxiety over asbestos in buildings began to grow in earnest last spring when the Environmental Protection Agency started highly publicized efforts to enforce its asbestos-in-schools rule. That regulation requires school administrators to inspect their buildings for asbestos-containing materials that crumble easily. If any is found, the schools must notify employees and parents that friable asbestos is present. EPA doesn't require that the material be removed, because the mere presence of asbestos is not necessarily hazardous, but recommends each school be evaluted on a case-by-case basis.

Telling parents that there is asbestos in their children's school but authorities aren't going to do anything about it, however, is like saying there's dynamite in the basement but there's no need to worry because the fuse isn't lit. Many parents have been frightened by statements that breathing a single fiber of asbestos can cause cancer years later. Panic and pressure ensue, and the result in many cases has been school closings and hasty removal of asbestos.

Similarly, asbestos is being taken out of many private and public office buildings. Often owners are motivated by fear they will be held liable for future asbestos-related diseases in the buildings' occupants. The bill for all this ripping out of asbestos may come to $20 billion, a staff member of the House Appropriations Committee estimates.

Yet no one is really sure how hazardous low levels of asbestos in the air are. And asbestos removal is a complicated task that, if done improperly, can leave higher air levels of asbestos in the building than existed before the work started.

Evaluating the risks that asbestos poses to the general population requires extrapolating data gathered in the workplace, where approximate fiber levels are known, to a much larger group of people exposed to much lower concentrations that are essentially unknown. Unlike the case with many toxic chemicals, a large amount of information on occupational hazards of asbestos is available. Even with that massive body of literature, however, it is very difficult to pin down accurately the risks to people who are exposed outside the workplace.

For example, last year a National Research Council (NRC) Committee on Nonoccupational Exposure to Asbestiform Fibers tried to quantify the risks of inhaling low levels of asbestos. The panel concluded that breathing the asbestos present in ambient air may be hazardous and some deaths from cancer probably will result. In contrast, a Canadian report by the Royal Commission on Matters of Health & Safety Arising from the Use of Asbestos in Ontario, also issued last year, finds "no evidence that disease afflicts individuals who breathe asbestos in outdoor air or inhale it as occupants of asbestos-containing buildings."

Although the NRC panel's stated conclusions are considerably more alarming than those of the Canadian group, the NRC committee states in the body of its report that the number of deaths expected to result from nonoccupational exposures to asbestos are very uncertain. In fact, in calculating the quantitative risks of developing cancer from such exposures to asbestos, the NRC panel estimated the risk could be as high as 1700 per million or could be nil.

"You must realize you can't pin down any specific numbers within that range," says committee member Jeremiah Lynch, manager of industrial hygiene for Exxon Chemical. As with all quantitative risk assessments, so many assumptions were necessary that the panel found it impossible to be exact.

Because of the weight a report from the prestigious NRC can carry with policy makers struggling to regulate asbestos, it's important to look at all the ifs, ands, and buts of the study. "A danger we all recognized when we worked on this was that people will overlook all the qualifiers," Lynch says.

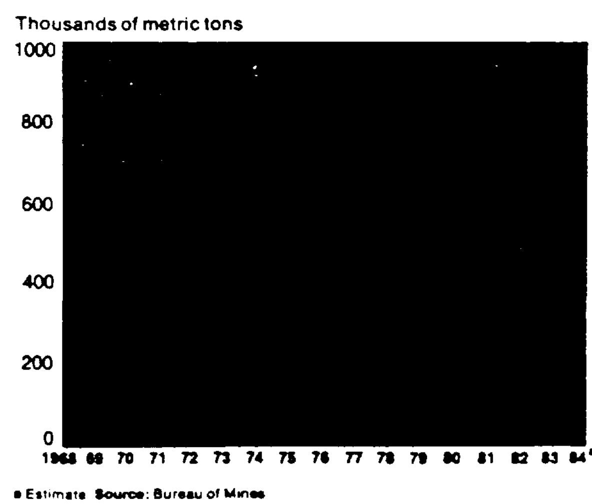
Risk assessment complications

To assess the health risk of a substance, its toxic effects must be identified, the relationship between dose and disease clarified, and the dose the population is exposed to determined. Uncertainties abound at every step.

In the case of asbestos, the toxic effects of high exposures are well documented. Among them are asbestosis, a type of pulmonary fibrosis or scarring of the lungs. Victims become short of breath and may eventually struggle so hard to breathe that they die of heart failure.

Asbestosis, which may develop after years of intense

U.S. consumption of asbestos peaked in 1973



* Estimate Source: Bureau of Mines

What's in a name? Even defining asbestos is difficult

Asbestos is not a discrete chemical compound or even a single group of minerals. The term is an imprecise commercial one that refers to several fibrous inorganic materials that are valued in industry for their high tensile strength and resistance to heat.

Unfortunately, sometimes minerals that do not meet mineralogists' criteria for asbestos also are lumped under the collective term. With medical scientists, federal regulators, industrial hygienists, contractors, unions, school boards, and even parent-teacher associations trying to tackle the problem of indoor exposure to asbestos, imprecise definitions only make a complicated problem even more difficult to handle.

The several mineral forms that are known commercially as asbestos vary in composition, fiber size, and crystal structure. They share what mineralogists call the "asbestiform habit"; that is, under certain rare conditions the minerals crystallize in bundles of hundreds or thousands of strong, flexible fibrils that look like organic fibers. However, the same minerals can—indeed usually do—crystallize in nonfibrous, rocklike forms.

Other minerals (for example, talc) also may sometimes form fibers under certain geological conditions. These fibers ought not to be called asbestos, mineralogists argue, because they lack the unique flexibility and tensile strength of true asbestos varieties. Asbestos fibers tend to cleave along the long axis of the fiber, yielding the thinner component fibrils, rather than break across the fiber axis into shorter lengths.

All commercial varieties of asbestos are silicates, that is, minerals where SiO_4 tetrahedra form the backbone of the crystal lattice. Silicate minerals are classified according to their crystal structures. Asbestiform mineral varieties occur as members of two groups: the serpentine and amphibole minerals.

Only one commercial asbestos mineral, chrysotile, belongs to the serpentine group. Serpentine is a magnesium silicate, in which layers of linked silica tetrahedra alternate with layers of magnesium oxide-hydroxide octahedra. In serpentine rock, the double layers result in platy crystals that tend to cleave into sheets like mica. In the asbestiform variety, however, the double layer rolls up on itself, curling as it grows to form long hollow tubes that are characteristic of chrysotile.

Chrysotile asbestos also is called white asbestos. Most asbestos being produced today is chrysotile, primarily from Canada and the U.S.S.R.

The other types of commercial asbestos all belong to the amphibole mineral group. Amphiboles are characterized by

Some silicates can crystallize as asbestos fibers

Mineral name	Chemical formula	Asbestiform variety
SERPENTINE GROUP		
Serpentine	$Mg_6Si_4O_{10}(OH)_8$	Chrysotile (white)
AMPHIBOLE GROUP		
Riebeckite	$Na_2Fe_3^{2+}Fe_2^{3+}Si_8O_{22}(OH,F)_2$	Crocidolite (blue)
Cummingtonite-grunerite	$(Mg,Fe^{2+})_7Si_8O_{22}(OH)_2$	Cummingtonite-grunerite asbestos (amosite, brown)
Tremolite-actinolite	$Ca_2(Mg,Fe^{2+})_5Si_8O_{22}(OH)_2$	Tremolite-actinolite asbestos
Anthophyllite	$(Mg,Fe^{2+})_7Si_8O_{22}(OH,F)_2$	Anthophyllite asbestos

Source: Bureau of Mines

exposure, was the first toxic effect of asbestos to be uncovered. Early occupational standards were designed to protect workers from that disease.

"Asbestosis occurs, for all practical purposes, only after exposure in the workplace," says Arthur M. Langer, a mineralogist who is associate director of the environmental sciences laboratory in Mount Sinai School of Medicine and a member of the NRC panel. The committee did not try to quantify the risk of asbestosis in its report on nonoccupational hazards, as it considered such risks in the general population to be nil.

Epidemiological studies have shown that occupational exposure to asbestos also can produce lung cancer, frequently occurring after a latency period of 10 to 30 years. Hammond and Selikoff documented that smoking cigarettes multiplies the risks of developing lung cancer from asbestos exposure. Lung cancer in asbestos-exposed workers could be cut significantly if they did not smoke cigarettes.

Mesothelioma is a very rare, always fatal, form of cancer of the lining of the lungs and abdominal cavity. The National Cancer Institute estimates there are only about 970 cases a year in the U.S. It is often called a "marker disease" for asbestos because most cases develop 20 to 40 years after exposure to that material.

However, in 10 to 30% of all mesothelioma victims no exposure to asbestos can be documented. Nevertheless, most researchers believe there would be few cases of mesothelioma in the absence of asbestos exposure.

Unlike lung cancer, the risk of developing mesothelioma is not tied to smoking. However, the risk seems to increase with the amount of time that passes after an individual is first exposed. That is what makes parents so fearful for their children's health. For if it takes, say, 40 years to develop mesothelioma, a child exposed to asbestos at age 10 would be more likely to get that cancer before dying of something else than an adult exposed at age 25.

Dose-response curves

The health risks of breathing high amounts of asbestos fibers are clear. What is less certain is the relationship between the amount of fiber inhaled and the amount of disease—that is, the dose-response curve.

Some occupational studies have complete enough data on dose levels to indicate that the risk of disease drops

Minerals that under certain geological conditions crystallize as asbestos fibers more often form typical rocks. Cummingtonite (right) is the mineral that may sometimes crystallize as asbestos fibers known as amosite (left)

strips of cations (usually calcium, sodium, magnesium, iron, or aluminum) sandwiched between two strips of linked silica tetrahedra. All the amphiboles have about the same basic structure but are substituted with different cations. Amphibole strips of asbestos are thought to grow in single crystal whiskers, often in veins of massive nonfibrous rock.

Only two amphiboles have been exploited commercially as asbestos to any significant degree. Crocidolite (blue asbestos), the asbestiform variety of the mineral riebeckite, currently is mined only in South Africa. Cummingtonite-grunerite asbestos (brown asbestos)—produced only in the Transvaal province of South Africa—is often called amosite from the acronym for the company Asbestos Mines of South Africa. Other amphiboles, such as anthophyllite and the tremolite-actinolite series, also occur in asbestiform varieties, but only rarely.

Further complicating matters is that minerals rarely occur as their pure, ideal composition but may contain a wide variety of contaminant ions. Batches of chrysotile from different mines, for example, are never identical.

Mineralogists themselves differ on the details of defining asbestos. But the fine points are even more likely to be obscured when the term asbestos is used by medical scientists or regulatory agencies. For instance, the legal regulatory definition of asbestos created by the Occupational Safety & Health Administration in setting occupational exposure limits is broader than the definition mineralogists and some other government agencies prefer. OSHA defines the minerals chrysotile, crocidolite, amosite, and all forms of anthophyllite, tremolite, and actinolite as asbestos.

"OSHA's terminology is so broad it includes a great deal of Earth's crust," says Malcolm Ross, mineralogist with the U.S. Geological Survey. OSHA is considering modifying its definition by adding the word "asbestiform" in front of anthophyllite, tremolite, and actinolite. That would bring OSHA's practice into line with the Mine Safety & Health Administration and the Consumer Product Safety Commission.

with decreasing exposure to asbestos. But there is no evidence in occupational studies to show there is a threshold level below which there are no adverse effects. "The problem is we haven't observed any safe levels," says Langer.

Some researchers think there are no safe levels of asbestos in the air. "As long as there's any exposure, there will be illness," says Selikoff. Accordingly, in formulating its report, the NRC committee chose to make the conservative assumption that no threshold level exists below which there isn't any risk of developing lung cancer or mesothelioma from asbestos.

Another problem in establishing a dose-response curve is the inaccuracy of old dose measurements. "We can't even be sure what was in the workplace 30 years ago," Langer says. "We only have good measurements since 1972," when OSHA began requiring them.

The shape of the dose-response curve at low doses isn't known and must be extrapolated from the high occupational exposures. "When extrapolating down to zero dose you must be careful," Langer says. "You are going beyond the hard data and extrapolating through doses for which no biological data are available."

As is often done in estimating the environmental risks of carcinogens, the NRC panel assumed the response was linear. This again is a conservative assumption that tends to overestimate the incidence of cancer at low doses.

The most controversial assumption in the NRC report is the panel's decision to lump together all forms of asbestos. The term asbestos is a commercial one that includes a number of mineral varieties that crystallize as strong, flexible fibers. A very vocal minority asserts that the type of asbestos most commonly used in the U.S., chrysotile, causes significantly less mesothelioma than other forms of asbestos, known as amphiboles. By grouping all the types together, these critics charge, the overall risks from asbestos are exaggerated.

"The [NRC] report is dangerous," says Andrew Churg, a pathologist at the University of British Columbia. "It ignores the difference between chrysotile and the amphiboles so it makes the mesothelioma risk seem much higher." Churg thinks the Canadian report, which cites only a weak association between chrysotile fibers and mesothelioma, is more accurate.

Churg's opinion is shared by others who object to the different species of asbestos being classed together.

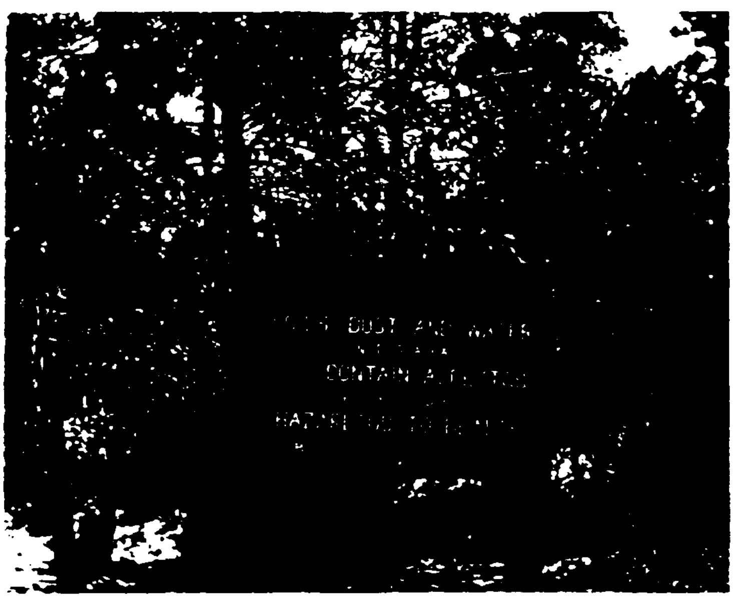
Malcolm Ross, a mineralogist with the U.S. Geological Survey, has made something of a crusade of his belief that chrysotile is not a significant health threat in a nonoccupational setting.

"When the public is led to believe that only the tiniest bit [of asbestos] will kill them, they're going to demand its removal," Ross says. "I'm troubled about where we are putting our money relative to the risks."

Ross says that to estimate accurately the health effects of each kind of asbestos separately, epidemiologists must look at the experience of asbestos miners and millers. He points specifically to chrysotile miners at Thetford Mines in Quebec. An epidemiological study of about 11,000 miners there by J. Corbett McDonald of McGill University found very few deaths from mesothelioma. In contrast, other studies have shown up to 10% of workers exposed to the amphibole called crocidolite die from mesothelioma.

The view that chrysotile asbestos is much less hazardous than the amphiboles forms the basis for regulation of asbestos in the U.K. and other members of the European Economic Community, where occupational standards allow higher levels of chrysotile than the amphiboles. The recent Ontario report recommends banning amphibole asbestos in Ontario, but not chrysotile. (The Canadian province of Quebec is a major producer of chrysotile asbestos; Ontario is not.) But in the U.S., Ross' position invites heated reaction.

"There's not a shred of evidence that some forms are less hazardous than others," Selikoff says. He points to a new study by Churg as the "smoking gun" that proves chrysotile is just as deadly as other forms of asbestos when it comes to mesothelioma. Churg and his coworkers found that of 90 chrysotile miners autopsied between 1980 and 1983, six died of mesothelioma.



U.S. Geological Survey photo

Sources of asbestos fibers in ambient air include natural rock. Rock outcrops near this park north of Coalinga, Calif., have been estimated to contain up to 50% short-fibered chrysotile asbestos

Churg himself, however, says his data should not be used to judge the incidence of mesothelioma. "These are selected autopsies," he says. "You have to conclude that chrysotile ore causes mesthelioma, but it's very dangerous to draw conclusions on incidence" because the autopsies are not a representative sample.

Even though there are substantially fewer deaths from mesothelioma tied to chrysotile, the NRC panel decided not to weigh the risk of the various forms of asbestos separately. That is largely because, considering smokers and nonsmokers together, the most common kind of cancer associated with asbestos is lung cancer, and chrysotile appears to be just as potent in causing lung tumors as the other types of asbestos. However, the risk of lung cancer in nonsmokers, according to the NRC panel, is less than that of mesothelioma.

"I think that Ross' basic assertion that the amphibole asbestos minerals produce more mesothelioma is correct," says committee member Langer. "But that doesn't mean chrysotile is a safe fiber. The lung cancer rate in some industries that use this fiber is very high. We still have to contend with it."

Langer also suggests that different disease rates experienced by miners as compared to industrial workers may be caused by variations in fiber properties. "The physical dimensions and surface characteristics may vary from industry to industry," he says, "and these may be important factors in chrysotile asbestos's differential toxicity." The Canadian report also notes differences in disease rates in different industries.

Exposure measurements

The nature of the fiber is only one factor in gauging the risk of low-level exposure to asbestos. Just as important are the intensity and duration of exposure. Measuring the amount of asbestos in ambient air is not a trivial problem, however. Neither is relating ambient air levels to the amounts of asbestos found in occupational settings.

Asbestos levels in the workplace are measured as the number of fibers in a given volume of air. For instance, OSHA's permissible exposure limit currently is two fibers of asbestos per cubic centimeter of air.

OSHA counts the number of fibers more than 5 µm long and at least three times longer than they are wide, using an optical microscope. Most fibers—perhaps 95%—in an occupational air sample are shorter than 5 µm, but OSHA reasons the longer fibers are a fair index of the entire amount.

The light microscopy technique normally used in occupational settings is phase-contrast microscopy. "It allows you to visualize materials with a long aspect ratio (ratio of length to width) that are greater than 0.2 µm in width," says John A. Small, a research chemist with the National Bureau of Standards. "But it doesn't distinguish among fibers of different origins. Under the phase-contrast counting methodology, glass, cellulose, and carbon fibers may be counted as asbestos," he says. Despite that limitation, phase-contrast microscopy is not a bad technique for an asbestos mill or plant, where one can reasonably assume that most of the fibers in the air are asbestos.

Asbestos abatement worker on the job last summer in Maplewood, N.J., elementary school

However, it was discovered early on that measuring asbestos in ambient air is very difficult. "It's a problem of a needle in a haystack," says Exxon's Lynch. "You find a little bit of asbestos in the presence of an enormous amount of particulate matter."

Therefore, electron microscopy techniques are used to measure asbestos accurately in ambient air. Samples are collected and treated to remove organic materials. Clumps of fibers are broken up so that the individual submicron-sized fibers can be seen. Transmission electron microscopy (TEM) can give the crystallographic structure of a fiber to distinguish asbestos from other fibers.

TEM is the definitive technique for measuring asbestos in ambient air but it costs $300 to $500 per sample. In addition, not many labs are set up to do that kind of analysis. "[Fewer] than 20 labs in the country have the combination of equipment and experience to do TEM," says Ian M. Stewart, vice president of McCrone Environmental Services, part of Walter C. McCrone Associates, a microscopy firm based in Chicago.

For that reason, scanning electron microscopy (SEM), which is cheaper and more accessible, is often suggested as a substitute for TEM. But Small and Stewart think the ability of SEM to distinguish chrysotile fibers is limited because of poor contrast.

In either electron microscopy technique, the number of fibers seen does not reflect the number in the original sample, because the sample preparation techniques break up the fibers. Therefore, the results are expressed as the mass of asbestos per volume of air.

Ambient air levels

Out in the country, away from man-made or natural sources of asbestos, there is less than 0.01 ng of asbestos per cubic meter of air, estimates William J. Nicholson, a physicist who is associate director of the environmental sciences laboratory at Mount Sinai School of Medicine. "But in a typical urban environment, there's about 3 ng per cu m over 24 hours," he adds. In the 1970s, concentrations of asbestos in New York City air ranged from 20 to 60 ng per cu m. Asbestos in outdoor air in cities probably stems from construction and remodeling or demolition work on buildings and from car brakes.

In 1978, Nicholson measured the levels of asbestos inside 10 schools that contained visibly damaged asbestos building materials. The concentration of chrysotile ranged from 9 to 1950 ng per cu m. Other studies have found asbestos air levels inside buildings with asbestos-containing materials ranging from 1 to more than 500 ng per cu m.

Judging whether these low concentrations of asbestos are a health risk requires relating them to the higher levels that epidemiologists found were hazardous to workers. Unfortunately, the occupational doses are measured in fibers per volume of air, whereas ambient air levels are measured in mass per volume of air. Accurately interconverting the two types of measurements is virtually impossible.

"The fibers suspended in ambient air are different from those in an occupational setting, not only in concentration but in size distribution," Lynch says. "Virtually all of the fibers [in ambient air] are small." That means that a nanogram of asbestos from the workplace might contain 2000 relatively large fibers, but the same mass in ambient air might be made up of 70,000 smaller fibers, to use an example from the NRC report.

However, the NRC panel decided to interconvert the exposure measurements from the two environments by assuming that the mass of an asbestos fiber found in the ambient air was equivalent to the mass of a fiber, of a particular dimension, found in the workplace. That assumption underestimates the number of fibers in ambient air and overestimates their size.

And that assumption also introduces a huge uncertainty in the panel's risk assessment, because fiber size has been hypothesized to be related to asbestos's toxicity. "That's why the lower limit of our risk assessment is zero," says Lynch. "Longer fibers are definitely toxic, but some researchers say that short fibers have no activity."

Some animal experiments indicate that shorter-length particles have little carcinogenic effect, perhaps because they are small enough to be cleared by macrophages. "However, the majority of the NRC committee does not agree that small fibers are totally inactive, although they may be less toxic," Lynch says. "It just isn't known." In contrast, the Canadian report concluded that thin asbestos fibers longer than 5 μm are hazardous.

Qualitative risk assessment

Using all of these assumptions, the NRC committee calculated the risks of developing mesothelioma and lung cancer from breathing asbestos in the ambient air over a lifetime. The panel calculated that at an exposure level of 0.0004 fiber per cc—about the level of asbestos

Underlying cause of asbestos's toxicity still unclear

"Everyone's got an interesting theory and there are data sets to support each and every one. But when you come down to the essentials—that is, what is it about asbestos that imparts its activity—your guess is as good as ours," Arthur M. Langer of Mount Sinai School of Medicine told federal officials last fall. The group was gathered for a briefing on the National Research Council's report on nonoccupational health risks of asbestiform fibers.

Although the state of scientific knowledge isn't quite so bad as Langer's remark implies, there's remarkably little that can be said with certainty about the root of asbestos' toxicity. Epidemiological studies indict asbestos as causing pulmonary fibrosis (asbestosis), lung cancer, mesothelioma (cancer of the lining of the lung and abdomen), and perhaps gastrointestinal cancer in workers exposed to large amounts in their jobs.

But only a few clues have yet been uncovered to link the physical and chemical properties of the various forms of asbestos to their biological activity. For example, it's not clear if the same properties trigger all the health effects or whether a different characteristic is responsible for asbestosis, say, than for lung cancer.

Important details that could help tie specific characteristics of asbestos fibers to disease are often missing from epidemiological studies that span several decades. Records of the exact types, origins, dimensions, and fiber concentrations of asbestos that workers were exposed to years ago may never have been kept or may have been lost. And inaccurate use of mineralogical terms in the scientific and medical literature prevents precise characterization of exposure.

More recent experiments in animals and in tissue culture—where conditions can be carefully controlled—overcome some of these difficulties. Interpreting such studies and extrapolating the conclusions to humans can be controversial, however.

The cellular mechanisms underlying asbestos's carcinogenicity are being explored. The multistage theory of cancer holds that two steps are necessary in the development of cancer. In the initiation step, DNA in a cell is damaged or mutated. In the promotion step, the altered cell is encouraged to divide and proliferate.

Although the evidence is contradictory, most laboratory studies show asbestos fibers don't damage DNA. Therefore, asbestos has not been shown experimentally to be an initiator of cancer.

Both laboratory and epidemiological studies point to asbestos's role as a promoter of lung cancer, however. For instance, asbestos exposure multiplies the risk of lung cancer from cigarette smoking. There also is evidence that asbestos may help carry certain carcinogenic hydrocarbons into cells. In addition, interaction of asbestos fibers with cell membranes favors the release of substances important to the carcinogenic process.

Crocidolite fibers in hamster respiratory tract. Small spherical cells are macrophages

A key determinant of asbestos's toxicity may be fiber size. The fiber has to reach the lung before it can do damage. "Fibers above a certain diameter are not even inhaled," says Brooke T. Mossman, associate professor of pathology at the University of Vermont and a member of the committee that prepared the NRC report. Those over about 3 µm in diameter probably are screened out by nasal hairs or other protective mechanisms in the upper respiratory tract.

Some researchers think that very small asbestos fibers also may not be toxic, although the NRC panel concluded no minimum size of fiber could be declared not to have any effect on health. Short fi-

in New York City air, according to the conversion factor the panel chose—the risks of developing mesothelioma range from zero to 350 per million.

At any exposure level, the risk of developing lung cancer depends on an individual's sex and on whether he or she smokes. The greatest risk is to male smokers, ranging from zero to 290 per million. Female nonsmokers were calculated to have the lowest risk, ranging from zero to 13 per million.

The committee also calculated the risk of a lifetime of exposure at a higher level, equivalent to the level that might be found in buildings with asbestos surfaces. Those risks ranged from zero to 1700 per million. The Canadian report, however, states that "asbestos in building air will almost never pose a health hazard to building occupants," unless elevated exposure is caused by disturbing the asbestos.

"There's an enormous amount of uncertainty" in assessing the risks of asbestos fibers in ambient air, Nicholson says. "The fibers are measured in so many different ways. There's the possibility of differential toxicity. The fiber dimensions are different in different environments." Nicholson recently prepared assessments of asbestos health risks for EPA and OSHA. His quantitative risks findings are generally in the same ball park as the NRC panel's.

"In all of these decisions we state our assumptions," says panel member John Van Ryzin, professor of biostatistics at Columbia University. "I was very insistent that we report what our uncertainties are."

The NRC panel's charge was to assess the risk from nonoccupational exposures to asbestos, not to recommend what to do about them. Yet the uncertainties inherent in calculating risk mean policy makers have difficult decisions ahead in tackling how to manage asbestos exposure.

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[illegible] More important, however, [illegible] body's system of defense against foreign matter. They cope with short fibers better. [illegible]

"Macrophages can swallow short fibers and transport them out of the lung," Mossman says. The cilia of the cells lining the trachea can sweep the engulfed fibers up to eventually be coughed out, spit out, or swallowed. Some may stay in the body, traveling to the lymph nodes, but there is no direct evidence that this causes disease, Mossman says.

Fibers of intermediate size, thin enough to enter the lung but too long to be entirely surrounded by macrophages, may be a culprit. In fact, one theory holds that it is the long, thin dimensions of asbestos fibers, rather than any specific chemical property, that it is the key to their toxicity.

That notion, known as the Stanton hypothesis, grew out of experiments performed by the late Mearl F. Stanton and coworkers at the National Cancer Institute. They inserted fibers of different sizes and types—the major forms of asbestos as well as other, nonasbestos fibers—into the lining of the lungs of rats. They concluded that the factor most tied to mesothelioma in their experiments was a particular size of fiber (specifically, fibers less than 0.25 µm in diameter and longer than 8 µm), rather than a particular chemical composition. Besides the various types of asbestos, fibers of borosilicate glass, potassium titanate, and some aluminum compounds caused mesotheliomas [illegible] naturally occurring zeolite fibers cause mesotheliomas in similar experiments. If size and shape, rather than chemistry, control the carcinogenicity of fibers, any proposed substitutes for asbestos need to be studied very carefully. For example, epidemiological studies of workers exposed to fibrous glass have shown a small increase in respiratory cancer. Until about 10 years ago, however, most glass fibers were larger than the size implicated in Stanton's studies. It may be too soon for any adverse effects from the thinner, more recently introduced glass fibers to show up.

The Stanton hypothesis is not without its critics, however. For one thing, it is experimentally difficult to completely separate fibers by size. A batch of fibers nominally of one length can contain fibers of quite different sizes. And milling minerals to reduce their length also can profoundly change their crystallinity and surface characteristics, says Langer.

Other workers have statistically reexamined Stanton's work with different results. French researchers conclude that the ratio of length to width (known as the aspect ratio) is most important and that it is not possible to separate the effects of length and width. Langer recalculated the data for crocidolite and judged fibers 4 to 8 µm long were most toxic, rather than those longer than 8 µm.

"Fiber dimension may be very important," Langer says, "but other factors are at least as important. You cannot dismiss [illegible] Langer and [illegible] have been [illegible] how minerals communicate with cell membranes through information on the mineral surface [illegible].

"Morphology may be important in getting the fiber to the site where it does damage," Langer says. "But once at the target site, surface characteristics take over. The nature of the chemical functionalities, their spacing, number, and geometrical configuration on a mineral surface are all going to affect how that mineral communicates and therefore interacts with a cell," he adds.

The question is more than academic. If surface chemistry is the key, then there would be a rational basis for the argument that certain forms of asbestos are less toxic than others. Some scientists believe, on the basis of epidemiological studies, that chrysotile fibers produce far less mesothelioma than crocidolite or amosite, although the issue is hotly debated.

If certain chemical functionalities could be pinpointed as the bad actors in asbestos toxicity, in theory modifications to the surface could result in less hazardous forms of asbestos. For instance, a Canadian government-industry organization called Société Nationale de l'Amiante is supporting research in Langer's lab and elsewhere on a modified phosphorylated chrysotile. "So far, the phosphorylated fiber appears to have far less membrane activity as compared to untreated fibers," Langer says. "The implications of producing a safe fiber are of vast pragmatic importance. The concept and work are exciting."

For the government to regulate a substance, it must first determine that the material poses a hazard. Then federal agencies must decide if they can take steps to reduce or eliminate the risks.

In the case of asbestos, there is clearly an occupational hazard to workers. OSHA currently is trying to lower the permissible exposure level in the workplace to either 0.5 or 0.2 fiber per cc.

The Consumer Product Safety Commission banned the use of asbestos in spackling compounds and artificial embers for fireplaces in the mid-1970s. A few years later, manufacturers voluntarily removed asbestos insulation from hair dryers after CPSC began an investigation.

EPA has the authority to ban hazardous chemicals and mixtures under the Toxic Substances Control Act. In the 1970s, it forbade further use of sprayed-on asbestos materials as a hazard both to the workers applying the material and to people near the construction site. That use of asbestos had become a popular method of fireproofing and insulating steel girders.

In 1983, EPA began drafting regulations to ban immediately some other uses of asbestos—including cement pipe and flooring and roofing products—and to phase out the rest over a 10-year period. But in early 1985, the agency said that, under TSCA, it must give other federal agencies a chance to regulate hazardous substances before it acts. So EPA has turned over its proposed ban on asbestos to OSHA and CPSC.

That move has angered critics in the environmental movement and trade unions and even within EPA itself, who suggest the action is simply an attempt by the Reagan Administration to stall further regulation of asbestos. However, if OSHA and CPSC don't move on the issue, the problem will end up back at EPA.

Yet some who are concerned about exposure to asbestos aren't sure that a ban on the material addresses the

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[illegible] from $100,000 to more than $1 million. The expense stems from the time and expertise needed from professionals in many different areas if the job is to be done properly.

When a building owner decides to have asbestos removed from a property, there often is only a potential hazard from asbestos that might be disturbed at a later date. But once the abatement project begins, there is an immediate hazard to the workers involved. And if the cleanup is not done with great care, there may be real danger to the occupants who return to a supposedly safe building.

"An asbestos removal project is really a demolition project that leaves the building standing," says Roger G. Morse, a Troy, N.Y., architect whose firm specializes in asbestos work. "At the same time, there's potential for contaminating the whole building. You need people who know what they are doing watching over the whole thing."

The asbestos abatement industry is growing by leaps and bounds and the potential for problems from shoddy work is growing with it. For example, many local [illegible] difficult to eliminate guys who [illegible] what they're doing [illegible] takes for a contractor to [illegible] $[illegible],000 to buy equipment." [illegible] new industry evolving more quickly than government can regulate it," says [illegible] W. Schopfel of [illegible] Contracting Co., Pennsauken, N.J. Schopfel is a charter member of the National Association of Asbestos Abatement Contractors, a nonprofit trade association formed in January 1984 to [illegible] standards for the industry.

In addition to the contractor whose workers actually will take out the asbestos, a removal project requires, at a minimum, an architect or engineer to draw up specifications and coordinate the work as well as an analyst and air-sampling laboratory to monitor fiber levels. Every employee must be trained in safe work practices, and the Occupational Safety & Health Administration requires they be given physicals at regular intervals.

Before the work can start, the contractor must notify local and state agencies and the Environmental Protection Agency, Schopfel says, and then wait the required period to give them time to respond. Next, the work site is sealed, [illegible]

Then, negative air pressure is [illegible] tained in the work area. That way, any leaks will be from the outside into the contaminated area, rather than the other way around. Air is drawn in from the outside and exhausted through high-efficiency particulate air filters (HEPA) to remove asbestos fibers.

Workers dressed in hooded coveralls—called moon suits—and wearing respirators then remove the material. A number of techniques, such as scraping, are used and the material must always be kept wet to keep down dust levels. The waste, still wet, is double bagged and placed in containers to be taken to a landfill each day. No material is allowed to accumulate. Both the transporter that carries the sealed waste and the landfill that receives the asbestos must be certified. EPA requires that the asbestos be buried under at least 6 inches of dirt within the day. Finally, the area is carefully

real risks. Substitutes must be adequately tested, for example. "I'm concerned that if some material is not called asbestos, it is automatically exonerated from biological wrongdoing," says Langer.

Nicholson points out that asbestos in most products being manufactured today—cement pipe, for example—is tightly bound and not likely to become airborne easily. "The current hazard is from asbestos already in place—about a million tons of friable asbestos in insulation and pipe lagging that's going to have to be removed someday. That's a much greater problem than continued use of asbestos."

Asbestos abatement

A recent EPA report estimates that 15 million children attend schools where friable asbestos is present. An EPA survey of buildings other than schools estimates that 700,000 commercial, residential apartment, and federal buildings contain friable asbestos. The only current federal regulation that requires asbestos be removed from buildings is an EPA rule saying asbestos materials must be taken out of a building before it is demolished.

Two factors, however, are encouraging a growing trend to rip asbestos materials out of buildings wherever these materials are found. One is EPA's asbestos-in-schools program, which requires school districts to inspect their buildings for crumbling asbestos. The second is building owners' fears that occupants may sue over future asbestos-related disease. Asbestos abatement—which includes both removal and sealing off asbestos in various ways—has become big business.

The asbestos-in-schools program has been lambasted from all sides for publicizing the presence of asbestos in schools but not giving school authorities enough help—either technical or financial—to deal with the problem rationally.

EPA publishes a booklet called "Guidance for Controlling Friable Asbestos-Containing Materials in Buildings" to help school authorities decide what to do when they find asbestos. It does not specify, however, that asbestos must be removed. Local officials must judge if that is necessary. Other options are to leave the asbestos-containing material alone, enclose it, or encapsulate it with a sealant that binds the fibers tightly. Many authorities in asbestos control agree that the problem is too complex to formulate general regulations that would fit every building situation.

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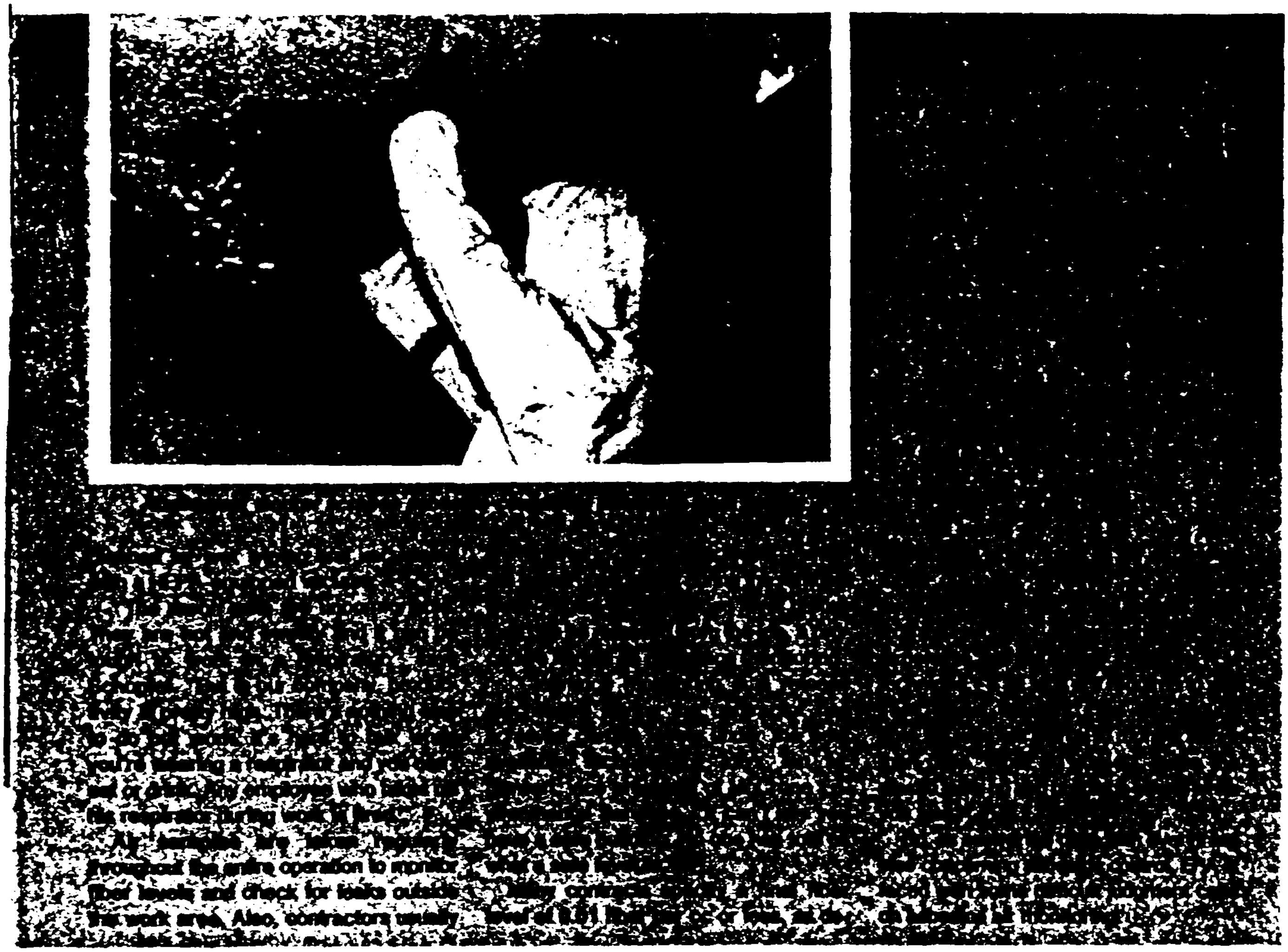
![]

"You have to decide on a case-by-case basis whether to remove asbestos," Selikoff says. "Asbestos does not constitute a hazard unless it is inhaled. Unless it can become airborne, there's no urgency in removing it. If it can be sealed off or is inaccessible and in good condition, it doesn't need to come out unless it will be disturbed by repairs or renovation. This can be planned for."

However, local school boards often lack the expertise and are too short of funds to hire experts to help them make the right decisions. "EPA is going in the right direction, but [it doesn't] have enough qualified people to supply guidance," Nicholson says. "Right now, some school administrators are so frightened that they panic when they see a crack in the ceiling. Others have the stuff falling all over and are not doing anything."

Says Susan Mazzochi, cofounder of Parents Against Asbestos Hazards in Schools, based in Maplewood, N.J.: "We discovered asbestos in our children's school and were shocked that the school board wasn't acting. The school board didn't want to do anything because it would cost money. In absence of any law that states how the problem should be addressed, it becomes a power struggle between the parents and the school board."

Another group that thinks EPA should take a more active role in asbestos abatement policy is the Service Employees International Union (SEIU), which represents about 100,000 school workers. Maintenance workers such as SEIU members are often the individuals expected to remove or clean up damaged asbestos materials in school buildings, sometimes with inadequate training and protective gear.

SEIU petitioned EPA in late 1983 to require corrective action when hazardous asbestos is found in schools and to issue regulations to protect school workers, who are not covered under OSHA. When EPA refused to act on all of the union's requests, SEIU filed a lawsuit against the agency in September 1984.

EPA is in an awkward position because no one can say exactly what levels of asbestos are hazardous. In certain situations where damaged asbestos is flaking into work areas and circulating through air-conditioning systems, the decision to remove it is straightforward. But most cases are not that simple.

"The appropriate action should be determined by a complete building survey by a qualified individual," says William H. Spain of the environmental health and safety division of Georgia Institute of Technology. Spain

NRC's estimated cancer risk has wide margin of uncertainty

Exposure group	Individual lifetime risk of developing cancer, per million[a]: Exposure at 0.0004 fiber/cc[b]	Exposure at 0.002 fiber/cc[c]
LUNG CANCER		
Male smoker	64 (0 to 290)[d]	320 (0 to 1500)
Female smoker	23 (0 to 110)	120 (0 to 530)
Male nonsmoker	6 (0 to 22)	29 (0 to 130)
Female nonsmoker	3 (0 to 13)	15 (0 to 66)
MESOTHELIOMA		
All	9 (0 to 350)	46 (0 to 1700)

Note: For example, the risk of developing lung cancer for a male smoker who is exposed throughout his lifetime to an asbestos concentration of 0.0004 fiber per cc probably is about 64 in 1 million, but may range from 0 to 290 in 1 million. a Lifetime assumed to be 73 years. Exposure occurs continually from birth. b Approximately equivalent to asbestos concentration in urban outside air. c Approximately equivalent to asbestos concentration in U.S. schoolrooms with asbestos surfaces. d Range of estimates. Source: "Asbestiform Fibers: Nonoccupational Health Risks," National Academy Press, 1984

and his colleagues in Georgia Tech's asbestos programs group offer courses for building owners, architects, contractors, and others on managing asbestos. Their course on supervising asbestos abatement contracts is so popular that they have offered it 15 times since its inception in May 1982.

Georgia Tech is the site of one of three new asbestos information centers, funded by EPA and opening this year to answer questions about controlling asbestos. "Bill Ewing [William M. Ewing, also at Georgia Tech] and I could spend 10 hours a day on the phone talking about asbestos," Spain says.

Spain does not think air levels of asbestos should be the criteria for determining the need for abatement. "Air samples are like a photograph, they reflect only the circumstances at that particular time. Air levels that are low during normal activities might be higher during certain maintenance procedures that might disturb the asbestos, like changing light fixtures or running telephone lines," he says.

Given the popular notion that even the smallest bit of asbestos is deadly, many school systems and building owners are rushing to take it out. Unfortunately, this can sometimes turn a potential risk into an actual one.

"If building surveys and abatement work are not done correctly, the hazard could be made many, many times worse than it was initially," Spain says. "A substantial, or at least a noticeable, portion of abatement projects are being done in such a way as to put people at risk." The Canadian report also points out that removal projects can increase the risks of asbestos-related disease.

The danger lies in not containing the asbestos as it is removed. Both abatement workers and bystanders then are exposed to loose fibers as the removal work is going on. In addition, asbestos fibers, which take a long time to settle out of the air, can become caught up in the air-circulation system of the building and subject the occupants to sizable doses once they return to a supposedly clean building.

Indeed, tenants of the 17th floor of the Medical Towers building in Houston have filed a $110 million suit against the building manager and a contractor who remodeled the 18th floor last summer. The plaintiffs charge they were exposed to asbestos dust and now have increased risk of getting cancer.

The consequences of acting too hastily to remove asbestos are also apparent in New Jersey, where about 300 schools were scheduled to have asbestos taken out last summer. As the opening of the fall school term approached, it became clear that many of the jobs had been done sloppily and with inadequate monitoring. Most of the schools opened on time anyway.

McCrone Environmental Services photo

Magnified 148X under polarized light, chrysotile fiber bundles appear blue and purple. The characteristic hollow-tube structure of individual chrysotile fibrils is visible in the transmission electron microphotograph (35,000X)

Property liability lawsuits multiplying rapidly

When Manville Corp. (formerly Johns-Manville) filed a bankruptcy petition in August 1982, it was seeking protection from millions of dollars in claims by more than 16,000 people suffering from asbestos-related diseases. Now, however, other asbestos manufacturers are being deluged with lawsuits from building owners. These fast-multiplying property damage suits may turn out to be even more expensive than the health-related ones.

For example, last September the state of Maryland filed suit against 47 asbestos producers for the cost of cleaning asbestos out of 3000 buildings owned by the state. "The suit asks for $500 million in compensatory damages," says Evelyn O. Cannon, assistant attorney general. "We also asked the court to require the defendants to come into the buildings, identify the asbestos, remove it, and replace it with substitutes," she adds. The first hearing in the state's suit is scheduled for later this month.

If the size of Maryland's suit turns out to be typical, a crude extrapolation yields many billions of dollars at stake in suits from state governments alone. Businesses, local governments, and private homeowners also are potential plaintiffs in such suits. So is the federal government, but the Department of Justice indicates it probably won't sue. However, a Justice Department report encourages school systems to try to recover the costs of their abatement projects from asbestos manufacturers.

A decision last fall by a federal judge in Philadelphia cleared the way for a class action suit by schools against asbestos producers. Judge James M. Kelly ruled that a combined suit would let thousands of small school districts sue to recover the money they've spent to remove asbestos without being burdened by prohibitively high legal costs. Districts may sue on their own for compensation, his ruling said, but all punitive damages will have to be part of the class action.

Because Manville is in bankruptcy, it can't be sued directly as the other asbestos producers can. Claimants against Manville instead must petition the bankruptcy court. When a deadline expired last Jan. 31, more than 3500 property damage claims had been filed. For other companies not under the protection of Chapter 11, the suits will continue to snowball.

"Most of the contractors who have been hired by the school boards to perform asbestos removal work have little experience in this specialized and sensitive field," states a report issued last August by New Jersey's Department of the Public Advocate. "Because many good contractors are overextended, there is a lack of qualified asbestos removal workers."

As a result, inspectors found workers tracking asbestos out of sealed areas, flushing asbestos down toilets, not wearing protective respirators or clothing, and hauling asbestos away in private cars, as well as numerous other abuses of good work practices.

To counter such abuses, there should be some way to demonstrate who's qualified to do asbestos abatement work. Some states already have contractor certification requirements. An incentive for the rest of the states to introduce certification procedures is built into the Asbestos School Hazard Abatement Act of 1984. That law, which gave EPA $50 million in fiscal 1985 to assist states and local school districts with asbestos control, requires states to certify contractors.

The asbestos programs group at Georgia Tech is developing a model one-week training program for asbestos abatement supervision under an EPA contract. Another organization, the National Asbestos Council (NAC)—composed of contractors, building owners, architects, analysts, and other professionals concerned about proper asbestos abatement—is developing training materials for small contractors and maintenance personnel who have to deal with asbestos.

A different problem is starting to put even well-qualified contractors out of work, however. "We're starting to hear of contractors that can no longer get liability insurance," says McCrone Environmental Services' Stewart, who is past president of NAC.

"In the past two weeks I've heard from at least 15 contractors who are losing their insurance," echoes Brent W. Schopfel, a contractor who is a charter member of the National Association of Asbestos Abatement Contractors. Insurance companies, burned by massive personal injury and property damage claims against asbestos manufacturers, are specifically excluding asbestos abatement work as contractors' general liability policies come up for renewal.

"If something isn't done, all of the abatement work is going to grind to a halt," says Stewart M. Huey, executive director of NAC. He suggests that state insurance commissioners may have to create an assigned risk pool, as is done for workmen's compensation. Or the federal government could start a reinsurance program, as is the case with flood and nuclear power plant insurance.

"It's a nasty problem and a lot of people are working on it," says Schopfel. "It's going to be an interesting summer."

All of the problems with asbestos abatement are exacerbated by panicky, oversimplified responses to a complex issue. "I think we ought to control asbestos," says Langer. "We should not tear it out indiscriminately and then tax society $20 billion. In some cases it may not have to be removed. Where it does, we don't have the trained people to remove it properly and we may increase risks by taking it out. We live in a chemical society. Let's learn to control and live with these materials." □

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